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Tables for the estimation of the internal rate of return of photovoltaic grid-connected systems

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Abstract

A continuous decrease trend in PV costs together with a wide variety of supporting measures have turned photovoltaic grid-connected systems (PVGCS) into a profitable investment when some economic conditions are met. The internal rate of return (IRR) is a meaningful parameter for prospective owners of these PV systems. Nevertheless, this parameter has to be estimated by means of non-analytical methods. This paper presents some easy-to-use tables addressed to estimate the IRR avoiding cumbersome calculations, which is an attractive feature for owners, marketers and designers. Firstly, current and near-term costs of PVGCS are reviewed, together with some financial incentives available at present. This introduces the economic scenario, where the tables are to be used. A short introduction to the economic analysis of these systems provides a solid ground to eventually present the tables intended to the estimation of the IRR. Lastly, three examples demonstrate the use of the tables.

Keywords: Economic analysis; Grid-connected; Financing

Contents

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1. Introduction

At the beginning of the 1990s, the main PV applications were stand-alone systems, communication and consumer products. However, PV grid-connected systems (PVGCS) have had the largest growth since 2000. In fact, grid-connected PV residential applications are estimated to have risen from a small 3.3% of the world PV market in 1993 to a large 55.5% in 2003 [1]. Apart from environmental awareness, this development has been brought mainly by means of a continuous decrease trend in PV costs together with a wide variety of promotion strategies and supporting programmes that different developed countries have launched.

Despite this optimistic horizon, cautious prospective owners, when approached by PV designers and marketers, obviously demand some information concerning the economic feasibility of their investment. In fact, profitability may be achieved under some conditions at present. This paper is intended to ease the estimation of the Internal Rate of Return (IRR) of a PVGCS-a meaningful profitability index for the possible owner-using classical analysis of investment projects. This estimation may be quickly achieved by some easy-to-use tables proposed here that take into account most available financial incentives today.

2. Costs, dissemination strategies and financial incentives

Wafer-type silicon modules accounted for some 89% of the market's share in 2003 [1]. Current and near-term costs of this technology range from 3000 to 8000 US\$ kWp^{-1} in PVGCS. Costs for these PV applications using other thin-film promising technologies span from 2000 to 7000 US\$ kWp^{-1} [2]. Prospects still forecast a prevailing market position for wafer-type silicon modules in the mid-term.

Some of those government strategies mentioned in Section 1 are addressed to reach a capacity or a number of PV systems installed, i.e. the German government '100,000 roofs solar power programme' completed at the end of 2003 [3], the USA 'million solar roofs initiative' programme [4], etc. Other strategies are intended to ensure that a certain

percentage of electricity is generated by renewable energy, such as those granted by the USA quotas or renewable portfolio standards (RPS), Australia's target addressed to generate approximately an additional 2% of their electricity from renewable energy sources (RES) by 2010, [4] or the European Union's White Paper target of 23% electricity from RES by 2010.

These strategies may be implemented with financial incentives, such as granting a subsidy per kWp capacity installed or a payment per kWh produced and sold. In other words, these financial incentives broadly fall into investment-focused (buy-down subsidy, soft loans, income tax incentives, etc.) and generation-based (enhanced feed-in tariffs, net metering, etc.) ones.

It is worth to mention some remarkable buy-down initiatives: the Japanese government has subsidised a third of the system installation, within the project for supporting new energy operators [5], the California State Government offers a subsidy of \$3.80 ACW^{-1} installed under the California Emerging Renewable Energy Buy-Down Program [6], a maximum buy-down amount up to 20% of the eligible cost of the project for PVCGS < 100 kW is offered in Spain [7], the Netherlands 'Energy Premium Regulation' (EPR) [8] offers a subsidy of 3.50 € Wp^{-1}, etc.

Soft loans programmes offer interest-free or, more commonly, low-interest loans (typically at some 2% annual interest rate) with different durations (e.g. 5, 7, 10 years) like those launched by some USA states, Germany, Spain, etc. [7,9–12]. Concerning feed-in tariffs, prices above the market level may be paid per kWh fed into the grid as an active promoting measure. Delivered electricity is sold to the utility at a unitary selling price of 0.457 € kWh^{-1} in Germany (year 2003), 0.60 € kWh^{-1} for PVGCS < 20 kWp in Austria, and 0.41 € kWh^{-1} for PVGCS < 100 kWp in Spain, just to give some outstanding examples.

3. Approach

From a strictly economic viewpoint, the purchase of a PV system means an expenditure of capital resources at a given time with the expectation of benefits in the form of solar electricity yield to be paid/saved to/by the user over the useful life of the system. Any economic assessment on such an investment requires a calculation of the involved cash flows as consistent as possible. Some remarkable contributions have been reported in this direction [13–19]. However, some available incentives at present have not been considered in these works. Some other good efforts have paid careful attention to cash flows in particular case studies of PV systems [9] or specific geographical areas [20]. One of the most general and comprehensive approaches to the issue found in recent literature is that proposed by Whisnant et al. [21]. Nevertheless, given the aims and scope of our work and also for the sake of simplicity, the analysis of cash flows related to PV systems referred here is similar to that presented by Nofuentes et al. [22]. Only buy-down incentives, soft loans for the whole remaining initial cost after the buy-down subsidy to be repaid in equal annual installments, and enhanced feed-in tariffs are considered in this work. Taxes from incomes derived from selling solar electricity and other tax considerations concerning interests paid on loans are left away, since all these facts depend on the owner's marginal tax rate, which lies out of the scope of this work.

4. Background

The especial features of PV systems together with the economic incentives taken into account in our analysis suggest that any cash flow involved in it should make a contribution to one of the following two concepts:

(a) The life-cycle cost of the system from the user standpoint (LCC_{USP})[1]
(b) The present worth of the cash inflows from the system.

Both concepts are reviewed below.

4.1. Life-cycle cost of the system from the user standpoint (LCC_{USP})

Parameter LCC_{USP} is the sum of the present worth of the initial user investment on the PVGCS ($PW[PV_{UIN}]$, in €) plus the present worth of the operation and maintenance cost ($PW[PV_{OM}]$, in €):

$$LCC_{USP} = PW[PV_{UIN}] + PW[PV_{OM}] \tag{1}$$

If PV_{IN} (€) is the initial investment on the PVGCS while PV_{BD} (€) is stated as the initial buy-down subsidy, $PV_{IN} - PV_{BD}$ is to be paid by the owner. However, if this amount is borrowed at an annual loan interest i_1, total payments of each year (ANN PMT, in €) during the loan duration (N_1, in years) can be set equal so that [23]:

$$\text{ANN PMT} = (PV_{IN} - PV_{BD})i_1 \left[\frac{(1+i_1)^{N_1}}{(1+i_1)^{N_1} - 1}\right] \tag{2}$$

So that:

$$PW[PV_{UIN}] = \text{ANN PMT}\frac{1-q^{N_1}}{1-q} \tag{3}$$

where $q = 1/(1+d)$. Factor d is the nominal discount rate. The actual discount rate (d_a) is derived from the latter by $d_a = (d-g)/(1+g)$, where g is the annual inflation rate.

If interest-free loans ($i_1 = 0$) are available, Eq. (2) turns into:

$$\text{ANN PMT} = \frac{PV_{IN} - PV_{BD}}{N_1} \tag{4}$$

Concerning $PW[PV_{OM}]$, it may be written as

$$PW[PV_{OM}] = PV_{AOM} = \frac{K_{PV}(1-K_{PV}^{N})}{1-K_{PV}} \tag{5}$$

where PV_{AOM} is the annual operation and maintenance cost [24,25] $= 0.01PV_{IN}$, and $K_{PV} = (1+\varepsilon_{PVOM})/(1+d)$. N is the life of the PVGCS. Factor ε_{PVOM} is the annual escalation rate of the operation and maintenance cost of the PV system.

[1]This concept is opposed to the life-cycle cost of the system from the grid standpoint (LCC_{GSP}) which considers costs that exclude tax exemptions, buy-down or grant policies, low or interest-free loans, etc. [18].

4.2. Present worth of the cash inflows from the system

The Present worth of the cash inflows from the system (PW[CIF(N)]) is related to government generation-based incentives. The most general case would assume that part of the annual PV yield (E_{PVs}, in kWh) is sold at a given price (p_{s}, in € kWh^{-1}), which is usually above the market level, while the remaining annual PV yield (E_{PVc}, in kWh) is consumed in situ. Consumption of E_{PVc} avoids buying electricity from the grid at a given price (p_{b}, in € kWh^{-1}), so PW[CIF(N)] may be written as:

$$\mathrm{PW[CIF}(N)] = p_{\mathrm{s}}E_{\mathrm{PVs}}\frac{K_{p_{\mathrm{s}}}(1-K_{p_{\mathrm{s}}}^{N})}{1-K_{p_{\mathrm{s}}}} + p_{\mathrm{b}}E_{\mathrm{PVc}}\frac{K_{p_{\mathrm{b}}}(1-K_{p_{\mathrm{b}}}^{N})}{1-K_{p_{\mathrm{b}}}} \tag{6}$$

where N (years) is the serviceable life of the system, $K_{p_{\mathrm{s}}} = (1+\varepsilon_{p_{\mathrm{s}}})/(1+d)$, $K_{p_{\mathrm{b}}} = (1+\varepsilon_{p_{\mathrm{b}}})/(1+d)$. Factors $\varepsilon_{p_{\mathrm{s}}}$ and $\varepsilon_{p_{\mathrm{b}}}$ stand for the annual increase rate of the energy price that is sold and consumed to/from the grid, respectively.

If all the annual PV delivered electricity ($E_{\mathrm{PV}} = E_{\mathrm{PVc}} + E_{\mathrm{PVs}}$, in kWh) is sold to the grid, Eq. (6) is simplified:

$$\mathrm{PW[CIF}(N)] = p_{\mathrm{s}}E_{\mathrm{PV}}\frac{K_{p_{\mathrm{s}}}(1-K_{p_{\mathrm{s}}}^{N})}{1-K_{p_{\mathrm{s}}}} \tag{7}$$

5. Short review of some profitability indices

Some 'classical' parameters intended to evaluate the profitability of a project are reviewed below. The concepts presented in Section 4 enable us to adapt and rewrite them conveniently for PVGCS.

5.1. Net present value

The net present value (NPV, in €) of an investment project is the sum of present values of all cash inflows and outflows related to the investment [13]. Therefore, the parameter NPV equals the present worth of the cash inflows from the system minus the life-cycle cost from the user standpoint. Thus:

$$\mathrm{NPV} = \mathrm{PW[CIF}(N)] - \mathrm{LCC_{USP}} \tag{8}$$

Obviously, a PVGCS should be viewed favourably if NPV > 0. However, this parameter fails to choose among two projects with the same NPV but different initial costs and duration.

5.2. Payback time

The payback time of an investment project (more properly, the discounted payback time, DPBT) is the required number of years for the present worth of the inflows to equal the present worth of the outflows. Evidently, profitability means that the discounted payback time should not exceed the serviceable life of the system (DPBT < N). Although easily understandable and straightforward, this parameter does not consider the cash flows

that are produced after the DPBT. Hence, it may hide sound financial opportunities for those deciding to invest on a PV system [9].

5.3. The internal rate of return

The internal rate of return (IRR) of an investment project is the value of the interest rate that leads to NPV = 0. This is to say:

$$\mathrm{NPV} = \mathrm{PW}[\mathrm{CIF}(N)] - \mathrm{LCC}_{\mathrm{USP}} = 0 \tag{9}$$

For a given project, the IRR equals the actual interest rate at which the project initial investment should be lent during its useful life to achieve the same profitability [17]. The actual internal rate of return ($\mathrm{IRR_a}$) is derived from IRR by $\mathrm{IRR_a} = (\mathrm{IRR} - g)/(1+g)$.

From an economic point of view, the PV system should be accepted if the IRR exceeds a profitability threshold fixed by the future owner. In this sense, this parameter is very important for the investor since it provides a meaningful estimation of the return of their investment. Unfortunately, Eq. (9) must be solved through non-analytical methods. This fact, together with the wide variety of available supporting measures for PV, turn solving NPV = 0 into a cumbersome procedure. This is why some easy-to-use tables addressed to estimate the value of IRR are presented in Section 6.

6. Tables

The value of the internal rate of return (IRR) for a given PV system, may be calculated through both parameters $\mathrm{LCC}_{\mathrm{USP}}$ and PW[CIF(N)]. When the life-cycle cost of the system from the user standpoint and the present worth of cash inflows from the system are equal, at the same value of d, the solution is found (IRR = d).

Tables 1–6 take into account many different economic scenarios for PVGCS. For convenience purposes, the tables to be presented here refer to normalised-per-kWp costs, incentives and electricity yields. The symbols used for these parameters are the same for those not normalised, but shown in brackets and with the subscript 'kWp'.

Tables 1–3 provide the present worth of cash inflows per kWp of a PVGCS ($[\mathrm{PW}[\mathrm{CIF}(N)]]_{\mathrm{kWp}}$) as a function of nominal discount rate (d), the annual yield per kWp of the system ($[E_{\mathrm{PV}}]_{\mathrm{kWp}}$) and the unitary price per kWh (p_{u}) to be paid to (which means selling PV electricity) or saved by (which means PV electricity consumption) the owner. A useful life for the system of $N = 25$ years has been assumed. Values of energy price p_{u} ranging from 0.2 to 0.6 €/kWh comprise most generation-based incentives for PV. The behaviour of electricity markets is always difficult to foresee. However, it seems that the rising trend of energy consumption-mainly due to China and other emerging economies-will make the world energy demand strong, pushing up electricity rates [26]. On the other hand, subsidies to solar electricity production may decrease with time. Bearing all this in mind, Table 1 assumes no annual increase rate of energy price ($\varepsilon_{p_{\mathrm{u}}} = 0$), whereas Table 2 assumes an annual decrease rate of energy price $\varepsilon_{p_{\mathrm{u}}} = -0.01$). Table 3 is the most favourable to PV, since it assumes $\varepsilon_{p_{\mathrm{u}}} = 0.01$.

Table 1
Present worth of cash inflows per kWp of a PVGCS ($[PW[CIF(N)]]_{kWp}$) as a function of the annual yield per kWp of the system ($[E_{PV}]_{kWp}$). The discount rate d and the unitary price per kWh (p_u) to be paid/saved to/by the user (annual increase rate of energy price $\varepsilon_{p_u} = 0$).

p_u (€ kWh^{-1})	$[E_{PV}]_{kWp}$ (kWh kWp^{-1} yr^{-1})					
	d	600	800	1000	1200	1400
0.2	0.01	2643	3524	4405	5286	6166
	0.03	2090	2786	3483	4179	4876
	0.05	1691	2255	2819	3383	3946
	0.07	1398	1865	2331	2797	3263
	0.09	1179	1572	1965	2357	2750
	0.11	1011	1347	1684	2021	2358
	0.13	880	1173	1466	1759	2052
	0.15	776	1034	1293	1551	1810
	0.17	692	923	1153	1384	1615
	0.19	623	831	1039	1247	1455
	0.21	567	755	944	1133	1322
	0.23	519	692	865	1038	1211
0.3	0.01	3964	5286	6607	7928	9250
	0.03	3134	4179	5224	6269	7314
	0.05	2537	3383	4228	5074	5919
	0.07	2098	2797	3496	4195	4895
	0.09	1768	2357	2947	3536	4125
	0.11	1516	2021	2527	3032	3537
	0.13	1319	1759	2199	2639	3079
	0.15	1164	1551	1939	2327	2715
	0.17	1038	1384	1730	2076	2422
	0.19	935	1247	1559	1870	2182
	0.21	850	1133	1416	1700	1983
	0.23	778	1038	1297	1556	1816
0.4	0.01	5286	7047	8809	10,571	12,333
	0.03	4179	5572	6965	8358	9751
	0.05	3383	4510	5638	6765	7893
	0.07	2797	3729	4661	5594	6526
	0.09	2357	3143	3929	4715	5501
	0.11	2021	2695	3369	4042	4716
	0.13	1759	2346	2932	3518	4105
	0.15	1551	2069	2586	3103	3620
	0.17	1384	1845	2306	2768	3229
	0.19	1247	1662	2078	2494	2909
	0.21	1133	1511	1889	2266	2644
	0.23	1038	1383	1729	2075	2421
0.5	0.01	6607	8809	11,012	13,214	15,416
	0.03	5224	6965	8707	10,448	12,189
	0.05	4228	5638	7047	8456	9866
	0.07	3496	4661	5827	6992	8158
	0.09	2947	3929	4911	5894	6876
	0.11	2527	3369	4211	5053	5895
	0.13	2199	2932	3665	4398	5131
	0.15	1939	2586	3232	3878	4525
	0.17	1730	2306	2883	3460	4036
	0.19	1559	2078	2598	3117	3637
	0.21	1416	1889	2361	2833	3305

Table 1 (*continued*)

p_u (€ kWh^{-1})	$[E_{PV}]_{kWp}$ (kWh kWp^{-1} yr^{-1})					
	d	600	800	1000	1200	1400
	0.23	1297	1729	2162	2594	3026
0.6	0.01	7928	10,571	13,214	15,857	18,499
	0.03	6269	8358	10,448	12,537	14,627
	0.05	5074	6765	8456	10,148	11,839
	0.07	4195	5594	6992	8391	9789
	0.09	3536	4715	5894	7072	8251
	0.11	3032	4042	5053	6064	7074
	0.13	2639	3518	4398	5278	6157
	0.15	2327	3103	3878	4654	5430
	0.17	2076	2768	3460	4152	4844
	0.19	1870	2494	3117	3741	4364
	0.21	1700	2266	2833	3399	3966
	0.23	1556	2075	2594	3113	3632

Table 2
Present worth of cash inflows per kWp of a PVGCS ($[PW[CIF(N)]]_{kWp}$) as a function of the annual yield per kWp of the system ($[E_{PV}]_{kWp}$). The discount rate d and the unitary price per kWh (p_u) to be paid/saved to/by the user (annual increase rate of energy price $\varepsilon_{p_u} = -0.01$).

p_u (€ kWh^{-1})	$[E_{PV}]_{kWp}$ (kWh kWp^{-1} yr^{-1})					
	d	600	800	1000	1200	1400
0.2	001	2616	3488	4361	5233	6105
	0.03	2069	2758	3448	4137	4827
	0.05	1674	2232	2791	3349	3907
	0.07	1384	1846	2307	2769	3230
	0.09	1167	1556	1945	2334	2723
	0.11	1001	1334	1668	2001	2335
	0.13	871	1161	1451	1742	2032
	0.15	768	1024	1280	1536	1792
	0.17	685	913	1142	1370	1598
	0.19	617	823	1029	1234	1440
	0.21	561	748	935	1122	1309
	0.23	514	685	856	1027	1198
0.3	0.01	3925	5233	6541	7849	9157
	0.03	3103	4137	5172	6206	7240
	0.05	2512	3349	4186	5023	5860
	0.07	2077	2769	3461	4153	4846
	0.09	1750	2334	2917	3501	4084
	0.11	1501	2001	2501	3002	3502
	0.13	1306	1742	2177	2612	3048
	0.15	1152	1536	1920	2304	2688
	0.17	1028	1370	1713	2055	2398
	0.19	926	1234	1543	1852	2160
	0.21	841	1122	1402	1683	1963
	0.23	770	1027	1284	1541	1798
0.4	0.01	5233	6977	8721	10,465	12,210

Table 2 (*continued*)

p_u (€ kWh^{-1})	$[E_{PV}]_{kWp}$ (kWh kWp^{-1} yr^{-1})					
	d	600	800	1000	1200	1400
	0.03	4137	5516	6896	8275	9654
	0.05	3349	4465	5581	6697	7814
	0.07	2769	3692	4615	5538	6461
	0.09	2334	3112	3890	4668	5446
	0.11	2001	2668	3335	4002	4669
	0.13	1742	2322	2903	3483	4064
	0.15	1536	2048	2560	3072	3584
	0.17	1370	1827	2283	2740	3197
	0.19	1234	1646	2057	2469	2880
	0.21	1122	1496	1870	2244	2618
	0.23	1027	1370	1712	2054	2397
0.5	0.01	6541	8721	10,901	13,082	15,262
	0.03	5172	6896	8620	10,343	12,067
	0.05	4186	5581	6977	8372	9767
	0.07	3461	4615	5769	6922	8076
	0.09	2917	3890	4862	5835	6807
	0.11	2501	3335	4169	5003	5836
	0.13	2177	2903	3628	4354	5080
	0.15	1920	2560	3200	3840	4480
	0.17	1713	2283	2854	3425	3996
	0.19	1543	2057	2572	3086	3600
	0.21	1402	1870	2337	2804	3272
	0.23	1284	1712	2140	2568	2996
0.6	0.01	7849	10,465	13,082	15,698	18,314
	0.03	6206	8275	10,343	12,412	14,481
	0.05	5023	6697	8372	10,046	11,721
	0.07	4153	5538	6922	8307	9691
	0.09	3501	4668	5835	7002	8168
	0.11	3002	4002	5003	6003	7004
	0.13	2612	3483	4354	5225	6096
	0.15	2304	3072	3840	4608	5376
	0.17	2055	2740	3425	4110	4795
	0.19	1852	2469	3086	3703	4320
	0.21	1683	2244	2804	3365	3926
	0.23	1541	2054	2568	3082	3595

Tables 4–6 provides the life-cycle cost of the system per kWp from the user standpoint $[LCC_{USP}]_{kWp}$, as a function of the initial investment in the PVGCS per kWp ($[PV_{IN}]_{kWp}$), the nominal discount rate and the initial cost buy-down subsidy per kWp ($[PV_{BD}]_{kWp}$). A useful life for the system of $N = 25$ years has also been assumed. The values of PV_{BD} have been selected so that most different buy-down subsidy programmes are considered. Also, soft loans are taken into account, to be repaid in N_1 equal annual installments at a given annual interest rate i_1. Tables 4 and 5 include the effect of a soft loan (for the whole remaining initial cost after the buy-down subsidy, to be repaid in N_1 equal annual installments), where $i_1 = 2\%$, $N_1 = 5$ years and $i_1 = 2\%$, $N_1 = 10$ years, respectively. These figures may be considered as typical values for subsidised loans, as anticipated in a previous section. Table 6 assumes no loans.

Table 3
Present worth of cash inflows per kWp of a PVGCS ($[\mathrm{PW[CIF}(N)]]_{\mathrm{kWp}}$) as a function of the annual yield per kWp of the system ($[E_{\mathrm{PV}}]_{\mathrm{kWp}}$). The discount rate d and the unitary price per kWh (p_{u}) to be paid/saved to/by the user (annual increase rate of energy price $\varepsilon_{p_{\mathrm{u}}} = 0.01$).

p_{u} (€ kWh^{-1})	$[E_{\mathrm{PV}}]_{\mathrm{kWp}}$ (kWh kWp^{-1} yr^{-1})					
	d	600	800	1000	1200	1400
0.2	0.01	2669	3559	4449	5338	6228
	0.03	2110	2814	3517	4221	4924
	0.05	1708	2278	2847	3416	3986
	0.07	1412	1883	2354	2825	3296
	0.09	1190	1587	1984	2381	2778
	0.11	1021	1361	1701	2041	2382
	0.13	888	1185	1481	1777	2073
	0.15	783	1045	1306	1567	1828
	0.17	699	932	1165	1398	1631
	0.19	630	840	1049	1259	1469
	0.21	572	763	954	1144	1335
	0.23	524	699	873	1048	1223
0.3	0.01	4004	5338	6673	8008	9342
	0.03	3166	4221	5276	6331	7387
	0.05	2562	3416	4270	5125	5979
	0.07	2119	2825	3531	4237	4943
	0.09	1786	2381	2976	3571	4167
	0.11	1531	2041	2552	3062	3573
	0.13	1333	1777	2221	2665	3109
	0.15	1175	1567	1959	2350	2742
	0.17	1048	1398	1747	2097	2446
	0.19	944	1259	1574	1889	2204
	0.21	858	1144	1431	1717	2003
	0.23	786	1048	1310	1572	1834
0.4	0.01	5338	7118	8897	10,677	12,456
	0.03	4221	5628	7035	8442	9849
	0.05	3416	4555	5694	6833	7972
	0.07	2825	3766	4708	5650	6591
	0.09	2381	3175	3968	4762	5556
	0.11	2041	2722	3402	4083	4763
	0.13	1777	2369	2961	3554	4146
	0.15	1567	2089	2612	3134	3656
	0.17	1398	1864	2330	2795	3261
	0.19	1259	1679	2099	2519	2938
	0.21	1144	1526	1907	2289	2670
	0.23	1048	1397	1747	2096	2445
0.5	0.01	6673	8897	11,122	13,346	15,570
	0.03	5276	7035	8794	10,552	12,311
	0.05	4270	5694	7117	8541	9964
	0.07	3531	4708	5885	7062	8239
	0.09	2976	3968	4960	5952	6945
	0.11	2552	3402	4253	5104	5954
	0.13	2221	2961	3702	4442	5182
	0.15	1959	2612	3264	3917	4570
	0.17	1747	2330	2912	3494	4077
	0.19	1574	2099	2624	3148	3673
	0.21	1431	1907	2384	2861	3338

Table 3 (*continued*)

p_u (€ kWh^{-1})	$[E_{PV}]_{kWp}$ (kWh kWp^{-1} yr^{-1})					
	d	600	800	1000	1200	1400
	0.23	1310	1747	2183	2620	3057
0.6	0.01	8008	10,677	13,346	16,015	18,684
	0.03	6331	8442	10,552	12,663	14,773
	0.05	5125	6833	8541	10,249	11,957
	0.07	4237	5650	7062	8474	9887
	0.09	3571	4762	5952	7143	8333
	0.11	3062	4083	5104	6124	7145
	0.13	2665	3554	4442	5330	6219
	0.15	2350	3134	3917	4701	5484
	0.17	2097	2795	3494	4193	4892
	0.19	1889	2519	3148	3778	4408
	0.21	1717	2289	2861	3433	4006
	0.23	1572	2096	2620	3144	3668

6.1. Use of the tables for the estimation of the value of IRR

The internal rate of return (IRR) equals the value of discount rate d that verifies Eq. (9). Values of IRR > 0 will be feasible solutions from an economic point, provided that a certain profitability hurdle set by the investor is reached.

Tables are used following the steps detailed below:

1. Choose the tables for the calculation of LCC_{USP}, according to the type of loan-if any-determined by i_1 and N_1 addressed to partly finance the initial investment. For the specific values of PV_{IN} and PV_{BD}, find a group of values LCC_{USP} for several values of discount rate d. Choose a value of d so that from this value of d, it follows a value of LCC_{USP}.
2. Choose the tables for the calculation of PW[CIF(N)], according to the annual increase rate of energy price (ε_{p_u}). For the specific values of E_{PV} and p_u, find a group of values PW[CIF(N)] for several values of discount rate d. Also choose the same value of d that was chosen in step 1. Select the corresponding value of PW[CIF(N)].
3. Subtract PW[CIF(N)] minus LCC_{USP}
4. Three cases may appear depending on the result of step 3:
   - 4.1. If the result of step 3 is equal to zero, then IRR $= d$.
   - 4.2. If the result of step 3 is negative, the discount rate d that is sought has a lower value than that chosen in step 1. Therefore, return to step 1 and choose the nearest lower value of d in this column. Iterations are continued until the difference obtained in step 3 turns into positive. Then, the solution is found: the value of IRR lies within the values of d of the last two iterations. The difference obtained in step 3 could not turn into positive at the lowest value of $d = 0.01$ considered in the tables. This means that the PVGCS project should be rejected since IRR < 0.
   - 4.3. If the result of step 3 is positive, the discount rate d that is sought has a higher value than that chosen in step 1. Therefore, return to step 1 and choose the nearest higher

Table 4
Life-cycle cost of the system per kWp from the user standpoint $[LCC_{USP}]_{kWp}$, as a function of the initial investment in the PVGCS per kWp ($[PV_{IN}]_{kWp}$). The nominal discount rate d and the initial cost buy-down subsidy per kWp ($[PV_{BD}]_{kWp}$). Loan duration $N_1 = 5$ years, $i_1 = 2\%$.

$[PV_{BD}]_{kWp}$ (€ kWp^{-1})	$[PV_{IN}]_{kWp}$ (€ kWp^{-1})						
	d	3000	4000	5000	6000	7000	8000
0	0.01	3750	5000	6250	7500	8749	9999
	0.03	3437	4583	5729	6875	8020	9166
	0.05	3178	4238	5297	6357	7416	8476
	0.07	2959	3946	4932	5919	6905	7891
	0.09	2770	3694	4617	5541	6464	7388
	0.11	2605	3473	4342	5210	6078	6947
	0.13	2459	3278	4098	4917	5737	6556
1500	0.01	2205	3455	4705	5955	7205	8455
	0.03	1980	3126	4271	5417	6563	7709
	0.05	1801	2860	3920	4979	6039	7098
	0.07	1654	2641	3627	4614	5600	6587
	0.09	1533	2456	3379	4303	5226	7388
	0.11	1429	2297	3165	4034	4902	5770
	0.13	1339	2159	2978	3798	4617	5437
	0.15	1261	2037	2812	3588	4364	5140
2000	0.01	1690	2940	4190	5440	6690	7940
	0.03	1494	2640	3786	4931	6077	7223
	0.05	1341	2401	3460	4520	5579	6639
	0.07	1219	2206	3192	4179	5165	6152
	0.09	1120	2043	2967	3890	4814	5737
	0.11	1037	1905	2773	3642	4510	5378
	0.13	966	1786	2605	3425	4244	5064
	0.15	905	1681	2457	3233	4008	4784
	0.17	852	1588	2325	3061	3797	4534
	0.19	805	1505	2206	2907	3607	4308
	0.21	762	1430	2098	2766	3434	4102
	0.23	724	1362	2001	2639	3277	3915
2500	0.01	1176	2425	3675	4925	6175	7425
	0.03	1008	2154	3300	4445	5591	6737
	0.05	882	1942	3001	4061	5120	6179
	0.07	785	1771	2757	3744	4730	5717
	0.09	707	1631	2554	3478	4401	6963
	0.11	645	1513	2381	3250	4118	4986
	0.13	593	1413	2232	3052	3871	4691
	0.17	512	1249	1985	2722	3458	4195
	0.19	480	1181	1882	2582	3283	3983
	0.21	452	1120	1788	2456	3124	3792
	0.23	427	1065	1703	2341	2979	3617
3000	0.01	661	1911	3161	4410	5660	6910
	0.03	522	1668	2814	3960	5105	6251
	0.05	423	1482	2542	3601	4661	5720
	0.07	350	1336	2322	3309	4295	5282
	0.09	295	1218	2142	3065	3988	4912
	0.11	253	1121	1989	2858	3726	4594
	0.13	220	1039	1859	2678	3498	4317
	0.15	194	970	1746	2521	3297	4073
	0.17	173	909	1646	2382	3119	3855

Table 4 (*continued*)

$[PV_{BD}]_{kWp}$ (€ kWp^{-1})	$[PV_{IN}]_{kWp}$ (€ kWp^{-1})						
	d	3000	4000	5000	6000	7000	8000
	0.19	156	857	1557	2258	2958	3659
	0.21	142	810	1478	2146	2814	3482
	0.23	130	768	1406	2044	2682	3320
3500	0.01		1396	2646	3896	5146	6395
	0.03		1182	2328	3474	4620	5765
	0.05		1023	2082	3142	4201	5261
	0.07		901	1888	2874	3860	4847
	0.09		806	1729	2652	3576	4499
	0.11		729	1597	2466	3334	4202
	0.13		666	1486	2305	3125	3944
	0.15		614	1390	2166	2942	3717
	0.17		570	1306	2043	2779	3516
	0.19		532	1233	1933	2634	3335
	0.21		499	1167	1835	2503	3171
	0.23		470	1108	1746	2384	3022

Table 5
Life-cycle cost of the system per kWp from the user standpoint $[LCC_{USP}]_{kWp}$, as a function of the initial investment in the PVGCS per kWp ($[PV_{IN}]_{kWp}$). The nominal discount rate d and the initial cost buy-down subsidy per kWp ($[PV_{BD}]_{kWp}$). Loan duration $N_1 = 10$ years, $i_1 = 2\%$.

$[PV_{BD}]_{kWp}$ (€ kWp^{-1})	$[PV_{IN}]_{kWp}$ (€ kWp^{-1})						
	d	3000	4000	5000	6000	7000	8000
0	0.01	3824	5099	6373	7648	8922	10,197
	0.03	3371	4495	5619	6743	7866	8990
	0.05	3002	4002	5003	6003	7004	8005
	0.07	2695	3594	4492	5391	6289	7188
	0.09	2438	3251	4063	4876	5689	6501
	0.11	2220	2959	3699	4439	5179	5919
	0.13	2032	2710	3387	4064	4742	5419
1500	0.01	2242	3517	4792	6066	7341	8616
	0.03	1947	3071	4194	5318	6442	7566
	0.05	1712	2713	3713	4714	5715	6715
	0.07	1522	2421	3319	4218	5116	6015
	0.09	1366	2179	2992	3804	4617	6501
	0.11	1236	1976	2716	3456	4195	4935
	0.13	1126	1803	2481	3158	3836	4513
	0.15	1032	1655	2279	2902	3525	4149
2000	0.01	1715	2990	4264	5539	6814	8088
	0.03	1472	2596	3720	4843	5967	7091
	0.05	1282	2283	3284	4284	5285	6285
	0.07	1132	2030	2928	3827	4725	5624
	0.09	1009	1822	2634	3447	4260	5073
	0.11	908	1648	2388	3128	3868	4608
	0.13	824	1501	2179	2856	3534	4211
	0.15	753	1376	1999	2623	3246	3869

Table 5 (*continued*)

$[PV_{BD}]_{kWp}$ (€ kWp^{-1})	$[PV_{IN}]_{kWp}$ (€ kWp^{-1})						
	d	3000	4000	5000	6000	7000	8000
	0.17	692	1268	1844	2420	2997	3573
	0.19	639	1174	1709	2244	2779	3314
	0.21	593	1092	1590	2089	2587	3086
	0.23	553	1019	1485	1951	2417	2884
2500	0.01	1188	2463	3737	5012	6286	7561
	0.03	997	2121	3245	4369	5492	6616
	0.05	853	1853	2854	3854	4855	5856
	0.07	741	1639	2537	3436	4334	5233
	0.09	652	1465	2277	3090	3903	5269
	0.11	580	1320	2060	2800	3540	4280
	0.13	522	1199	1877	2554	3231	3909
	0.15	473	1097	1720	2343	2967	3590
	0.17	432	1009	1585	2161	2737	3314
	0.19	397	932	1467	2002	2537	3072
	0.21	367	866	1364	1863	2361	2860
	0.23	341	807	1274	1740	2206	2672
3000	0.01	661	1935	3210	4485	5759	7034
	0.03	522	1646	2770	3894	5017	6141
	0.05	423	1423	2424	3425	4425	5426
	0.07	350	1248	2147	3045	3943	4842
	0.09	295	1107	1920	2733	3545	4358
	0.11	253	992	1732	2472	3212	3952
	0.13	220	897	1575	2252	2929	3607
	0.15	194	817	1441	2064	2687	3311
	0.17	173	749	1326	1902	2478	3054
	0.19	156	691	1226	1761	2296	2831
	0.21	142	640	1139	1637	2136	2634
	0.23	130	596	1062	1528	1994	2461
3500	0.01		1408	2683	3957	5232	6507
	0.03		1171	2295	3419	4543	5666
	0.05		994	1994	2995	3995	4996
	0.07		857	1756	2654	3552	4451
	0.09		750	1563	2375	3188	4001
	0.11		665	1405	2144	2884	3624
	0.13		595	1273	1950	2627	3305
	0.15		538	1161	1785	2408	3031
	0.17		490	1066	1643	2219	2795
	0.19		449	984	1519	2054	2589
	0.21		415	913	1412	1910	2409
	0.23		384	851	1317	1783	2249

value of *d* in this column. Iterations are continued until the difference obtained in step 3 turns into negative. Then, the solution is found: the value of IRR lies within the values of *d* of the last two iterations. The difference obtained in step 3 could not turn into negative at the highest value of *d* considered in the tables. In this case, the tables only provide a lower bound for IRR which is equal to the last tried value of *d*.

Table 6
Life-cycle cost of the system per kWp from the user standpoint $[LCC_{USP}]_{kWp}$, as a function of the initial investment in the PVGCS per kWp ($[PV_{IN}]_{kWp}$). The nominal discount rate d and the initial cost buy-down subsidy per kWp ($[PV_{BD}]_{kWp}$). No loans available.

$[PV_{BD}]_{kWp}$ (€ kWp^{-1})	$[PV_{IN}]_{kWp}$ (€ kWp^{-1})						
	d	3000	4000	5000	6000	7000	8000
0	0.01	3661	4881	6101	7321	8542	9762
	0.03	3522	4697	5871	7045	8219	9393
	0.05	3423	4564	5705	6846	7987	9128
	0.07	3350	4466	5583	6699	7816	8932
	0.09	3295	4393	5491	6589	7688	8786
	0.11	3253	4337	5421	6505	7590	8674
	0.13	3220	4293	5366	6440	7513	8586
1500	0.01	2161	3381	4601	5821	7042	8262
	0.03	2022	3197	4371	5545	6719	7893
	0.05	1923	3064	4205	5346	6487	7628
	0.07	1850	2966	4083	5199	6316	7432
	0.09	1795	2893	3991	5089	6188	8786
	0.11	1753	2837	3921	5005	6090	7174
	0.13	1720	2793	3866	4940	6013	7086
	0.15	1694	2759	3823	4888	5952	7017
2000	0.01	1661	2881	4101	5321	6542	7762
	0.03	1522	2697	3871	5045	6219	7393
	0.05	1423	2564	3705	4846	5987	7128
	0.07	1350	2466	3583	4699	5816	6932
	0.09	1295	2393	3491	4589	5688	6786
	0.11	1253	2337	3421	4505	5590	6674
	0.13	1220	2293	3366	4440	5513	6586
	0.15	1194	2259	3323	4388	5452	6517
	0.17	1173	2231	3288	4346	5404	6461
	0.19	1156	2208	3260	4312	5364	6416
	0.21	1142	2189	3236	4283	5330	6378
	0.23	1130	2173	3216	4259	5303	6346
2500	0.01	1161	2381	3601	4821	6042	7262
	0.03	1022	2197	3371	4545	5719	6893
	0.05	923	2064	3205	4346	5487	6628
	0.07	850	1966	3083	4199	5316	6432
	0.09	795	1893	2991	4089	5188	6286
	0.11	753	1837	2921	4005	5090	6174
	0.13	720	1793	2866	3940	5013	6086
	0.15	694	1759	2823	3888	4952	6017
	0.17	673	1731	2788	3846	4904	5961
	0.19	656	1708	2760	3812	4864	5916
	0.21	642	1689	2736	3783	4830	5878
	0.23	630	1673	2716	3759	4803	5846
3000	0.01	661	1881	3101	4321	5542	6762
	0.03	522	1697	2871	4045	5219	6393
	0.05	423	1564	2705	3846	4987	6128
	0.07	350	1466	2583	3699	4816	5932
	0.09	295	1393	2491	3589	4688	5786
	0.11	253	1337	2421	3505	4590	5674
	0.13	220	1293	2366	3440	4513	5586
	0.15	194	1259	2323	3388	4452	5517

Table 6 (*continued*)

$[PV_{BD}]_{kWp}$ (€ kWp^{-1})	$[PV_{IN}]_{kWp}$ (€ kWp^{-1})						
	d	3000	4000	5000	6000	7000	8000
	0.17	173	1231	2288	3346	4404	5461
	0.19	156	1208	2260	3312	4364	5416
	0.21	142	1189	2236	3283	4330	5378
	0.23	130	1173	2216	3259	4303	5346
3500	0.01		1381	2601	3821	5042	6262
	0.03		1197	2371	3545	4719	5893
	0.05		1064	2205	3346	4487	5628
	0.07		966	2083	3199	4316	5432
	0.09		893	1991	3089	4188	5286
	0.11		837	1921	3005	4090	5174
	0.13		793	1866	2940	4013	5086
	0.15		759	1823	2888	3952	5017
	0.17		731	1788	2846	3904	4961
	0.19		708	1760	2812	3864	4916
	0.21		689	1736	2783	3830	4878
	0.23		673	1716	2759	3803	4846

7. Examples

Some examples described in this section are intended to achieve a better understanding of the use of the tables proposed in our work. Only two iterations are shown in each example, with which the procedure is sufficiently clarified.

7.1. Example 1

Let us consider a 8-kWp PVGCS, with $[PV_{IN}]_{kWp} = 7000$ € kWp^{-1}, $[PV_{BD}]_{kWp} = 2500$ € kWp^{-1}, $[E_{PV}]_{kWp} = 1200\ kWh\ kWp^{-1}\ yr^{-1}$. All PV-generated electricity is sold to the grid at 0.4 € kWh^{-1}. A 5-year and 2%-interest loan is offered to the user ($N_1 = 5, i_1 = 2\%$). A negligible increase of the energy price is expected, this means $\varepsilon_{p_u} = 0$. A useful life of $N = 25$ years is assumed for the system. We will determine the internal rate of return (IRR) of this system.

Use of the tables for this example:

1. From Table 4, column 5 and rows, where $[PV_{BD}]_{kWp} = 2500$ € kWp^{-1} are considered. Let us choose a value of $d = 0.09$, so that $[LCC_{USP}]_{kWp} = 4401$ € kWp^{-1}.
2. From Table 1, column 4 and rows, where $p_u = 0.4$ € kWh^{-1} are considered. It follows from the row corresponding to the same value of $d = 0.09$ that $PW[CIF(N)]_{kWp} = 4715$ € kWp^{-1}.
3. Let us subtract $PW[CIF(N)] - LCC_{USP} = 314$ € kWp^{-1}.
4. Since $PW[CIF(N)] - LCC_{USP} > 0$, parameter IRR has a higher value. Therefore, let us return to step 1 and try with $d = 0.11$.
1. From Table 4, column 5 and rows, where $[PV_{BD}]_{kWp} = 2500$ € kWp^{-1} are considered again. Let us choose a value of $d = 0.11$, so that $[LCC_{USP}]_{kWp} = 4118$ € kWp^{-1}.

2. From Table 1, column 4 and rows, where $p_u = 0.4\,\text{kWh}^{-1}$ are considered again. It follows from the row corresponding to the same value of $d = 0.11$ that $\text{PW}[\text{CIF}(N)]_{\text{kWp}} = 4042\,€\,\text{kWp}^{-1}$.
3. Let us subtract $\text{PW}[\text{CIF}(N)] - \text{LCC}_{\text{USP}} = -76\,€\,\text{kWp}^{-1}$.
4. Since the difference obtained in step 3 turns into negative, the solution is found: the value of IRR lies within 9–11%.

7.2. Example 2

Let us consider a 3-kWp PVGCS, where PV electricity that is fed to the grid is paid to the user at $p_s = 0.4\,€\,\text{kWh}^{-1}$. PV electricity consumed by the user saves money at $p_b = 0.2\,€\,\text{kWh}^{-1}$. The annual PV electricity yield per kWp which is to be sold to the grid and consumed in situ are estimated as $[E_{\text{PVs}}]_{\text{kWp}} = 800\,\text{kWh}\,\text{kWp}^{-1}\,\text{yr}^{-1}$ and $[E_{\text{PVc}}]_{\text{kWp}} = 600\,\text{kWh}\,\text{kWp}^{-1}\,\text{yr}^{-1}$, respectively, with $[E_{\text{PV}}]_{\text{kWp}} = [E_{\text{PVs}}]_{\text{kWp}} + [E_{\text{PVc}}]_{\text{kWp}} = 1400\,\text{kWh}\,\text{kWp}^{-1}\,\text{yr}^{-1}$. This means an average energy unitary price of $p_u = (p_s[E_{\text{PVs}}]_{\text{kWp}} + p_b[E_{\text{PVc}}]_{\text{kWp}})/[E_{\text{PV}}]_{\text{kWp}} = 0.31\,€\,\text{kWh}^{-1}$. Besides, $[\text{PV}_{\text{IN}}]_{\text{kWp}} = 7000\,€\,\text{kWp}^{-1}$ and $[\text{PV}_{\text{BD}}]_{\text{kWp}} = 1500\,€\,\text{kWp}^{-1}$. A 10-year and 2%-interest loan is offered to the user ($N_1 = 10$, $i_1 = 2\%$). A decrease of the energy price is expected through the serviceable life of the PVGCS, this is $\varepsilon_{p_u} = 0.01$. A useful life of $N = 25$ years is assumed for the system. We will determine the nominal internal rate of return (IRR) of this system.

Use of the tables for this example:

1. From Table 5, column 5 and rows, where $[\text{PV}_{\text{BD}}]_{\text{kWp}} = 1500\,€\,\text{kWp}^{-1}$ are considered. Let us choose a value of $d = 0.07$, so that $[\text{LCC}_{\text{USP}}]_{\text{kWp}} = 5116\,€\,\text{kWp}^{-1}$.
2. From Table 3, column 5 and the rows, where $p_u = 0.3\,€\,\text{kWh}^{-1}$ are considered. It follows from the row corresponding to the same value of $d = 0.07$ that $\text{PW}[\text{CIF}(N)]_{\text{kWp}} = 4943\,€\,\text{kWp}^{-1}$.
3. Let us subtract $\text{PW}[\text{CIF}(N)] - \text{LCC}_{\text{USP}} = -173\,€\,\text{kWp}^{-1}$.
4. Since $\text{PW}[\text{CIF}(N)] - \text{LCC}_{\text{USP}} < 0$, parameter IRR has a lower value. Therefore, let us return to step 1 and try with $d = 0.05$.
1. From Table 5, column 5 and rows, where $[\text{PV}_{\text{BD}}]_{\text{kWp}} = 1500\,€\,\text{kWp}^{-1}$ are considered again. Let us choose a value of $d = 0.05$, so that $[\text{LCC}_{\text{USP}}]_{\text{kWp}} = 5715\,€\,\text{kWp}^{-1}$.
2. From Table 3, column 5 and the rows, where $p_u = 0.5\,€\,\text{kWh}^{-1}$ are considered again. It follows from the row corresponding to the same value of $d = 0.05$ that $\text{PW}[\text{CIF}(N)]_{\text{kWp}} = 5979\,€\,\text{kWp}^{-1}$.
3. Let us subtract $\text{PW}[\text{CIF}(N)] - \text{LCC}_{\text{USP}} = 264\,€\,\text{kWp}^{-1}$.
4. Since the difference obtained in step 3 turns into positive, the solution is found: the value of IRR lies within 5–7%.

7.3. Example 3

Let us consider a 4-kWp PVGCS, with $[\text{PV}_{\text{IN}}]_{\text{kWp}} = 6000\,€\,\text{kWp}^{-1}$, $[E_{\text{PV}}]_{\text{kWp}} = 1000\,\text{kWh}\,\text{kWp}^{-1}\,\text{yr}^{-1}$ and $[\text{PV}_{\text{BD}}]_{\text{kWp}} = 3000\,€\,\text{kWp}^{-1}$. All PV-generated electricity is sold to the grid at $0.2\,€\,\text{kWh}^{-1}$. A 5-year and 2%-interest loan is offered to the user ($N_1 = 5$, $i_1 = 2\%$). A decrease of the energy price is expected through the serviceable life of the PVGCS, this is $\varepsilon_{p_u} = -0.01$. A useful life of $N = 25$ years is assumed for the system. We will determine the nominal internal rate of return (IRR) of this system.

Use of the tables for this example:

1. From Table 4, column 4 and rows, where $[PV_{BD}]_{kWp} = 3000$ € kWp^{-1} are considered. Let us choose a value of $d = 0.03$, so that $[LCC_{USP}]_{kWp} = 3960$ € kWp^{-1}.
2. From Table 2, column 3 and rows, where $p_u = 0.2$ € kWh^{-1} are considered again. It follows from the row corresponding to the same value of $d = 0.03$ that $PW[CIF(N)]_{kWp} = 3448$ € kWp^{-1}.
3. Let us subtract $PW[CIF(N)] - LCC_{USP} = -512$ € kWp^{-1}.
4. Since $PW[CIF(N)] - LCC_{USP} < 0$, parameter IRR has a lower value. Therefore, let us return to step 1 and try with $d = 0.01$.
1. From Table 4, column 4 and rows, where $[PV_{BD}]_{kWp} = 3000$ € kWp^{-1} are considered again. Let us choose a value of $d = 0.01$, so that $[LCC_{USP}]_{kWp} = 4410$ € kWp^{-1}.
2. From Table 2, column 3 and rows, where $p_u = 0.2$ € kWh^{-1} are considered again. It follows from the row corresponding to the same value of $d = 0.01$ that $PW[CIF(N)]_{kWp} = 4361$ € kWp^{-1}.
3. Let us subtract $PW[CIF(N)] - LCC_{USP} = -49$ € kWp^{-1}.
4. It stems from $PW[CIF(N)] - LCC_{USP} < 0$ that the solution is $IRR < 0.01$. The investment on the PVGCS should be rejected if the decision is driven by exclusively economic criteria.

8. Conclusions

Cost-effectiveness in PVGCS may be achieved under some specific conditions taking into account available investment-focused and generation-based incentives. In contrast to some other profitability indices of an investment project, the internal rate of return provides some straightforward meaningful information to the investor, but its calculation requires non-analytical methods. Six tables addressed to PV designers and owners have been presented intended to ease the estimate of this parameter. Since these tables consider most existing PV supporting measures and different energy cost forecasts, they turn out to be valuable tools to make a quick assessment on the profitability of specific PVGCS projects.

Appendix. Terminology

ANN PMT	Total payments of each year on borrowed money (€).
$[E_{PV}]_{kWp}$	Normalised (per kWp) annual PV electricity yield ($kWh\,kWp^{-1}\,yr^{-1}$).
$[E_{PVc}]_{kWp}$	Normalised (per kWp) annual PV electricity yield which is consumed in situ by the user ($kWh\,kWp^{-1}\,yr^{-1}$).
$[E_{PVs}]_{kWp}$	Normalised (per kWp) annual PV electricity yield which is sold to the grid ($kWh\,kWp^{-1}\,yr^{-1}$).
$[LCC_{USP}]_{kWp}$	Normalised (per kWp) life-cycle cost of the PVGCS from the user standpoint (€ kWp^{-1}).
$[PV_{BD}]_{kWp}$	Normalised (per kWp) initial cost buy-down subsidy (€ kWp^{-1}).
$[PV_{IN}]_{kWp}$	Normalised (per kWp) initial investment on the PVGCS (€ kWp^{-1}).
$[PW[CIF(N)]]_{kWp}$	Normalised (per kWp) present worth of the cash inflows from a PVGCS through its useful life (€ kWp^{-1}).

d	Nominal discount rate.
d_a	Actual discount rate.
E_{PV}	Annual PV electricity yield (kWh).
E_{PVc}	Annual PV electricity yield which is consumed in situ by the user (kWh).
E_{PVs}	Annual PV electricity yield which is sold to the grid (kWh).
i_l	Annual loan interest.
g	Annual inflation rate.
IRR	Internal rate of return.
K_{PV}	$(1+\varepsilon_{PVOM})/(1+d)$.
LCC_{USP}	Life-cycle cost of the PVGCS from the user standpoint (€).
N	Useful life of the PVGCS (years).
N_l	Time duration of loan (years).
NPV	Net present value (€).
p_s	PV-electricity unitary selling price (€ kWh^{-1}).
p_b	Grid-electricity unitary buying price (€ kWh^{-1}).
p_u	PV-electricity unitary price paid/saved to/by the user (€ kWh^{-1}).
PV_{AOM}	Annual operation and maintenance cost of the PVGCS (€).
PV_{BD}	Initial cost buy-down subsidy (€).
PV_{IN}	Initial investment on the PVGCS (€).
$PW[CIF(N)]$	Present worth of the cash inflows from a PVGCS through its useful life (€).
$PW[PV_{OM}]$	Present worth of the PVGCS operation and maintenance cost (€).
$PW[PV_{UIN}]$	Present worth of the user initial investment on the PVGCS (€).
q	$1/(1+d)$.
ε_{p_b}	Annual increase rate of the energy price consumed from the grid.
ε_{p_s}	Annual increase rate of the energy price sold to the grid.
ε_{p_u}	Annual increase rate of the energy price consumed/sold from/to the grid.
ε_{PVOM}	Annual escalation rate of the operation and maintenance cost of the PVGCS.

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